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## Description

This invention relates to a semiconductor device manufacturing apparatus and, more particularly, to an immersion type projection exposure apparatus for lithographically printing a fine circuit pattern on a substrate, such as a wafer, during semiconductor manufacturing processes.

With miniaturization of each semiconductor device, the wavelength of used exposure light has been changed from g-line of a high pressure Hg lamp to i-line of shorter wavelength. The numerical aperture (NA) of a projection lens has to be made larger to meet the requirement of a high resolution, and the depth of focus becomes smaller. As is well known, the relationship can be represented by the following equation:

$$\text{Resolution} = k_1 (\lambda/NA)$$

$$\text{Depth of Focus} = \pm k_2 \lambda/NA^2$$

where  $\lambda$  is the wavelength of the light source used for the exposure process, NA is the numerical aperture of the projection lens, and  $k_1$  and  $k_2$  are coefficients related to the process.

Recently, use of excimer (KrF or ArF) light having a wavelength shorter than g-line or i-line of conventional high pressure Hg lamps, or use of X-ray lithography or electron beam (EB) direct pattern drawing has been proposed. On the other hand, use of a phase shift mask or modification of illumination has been proposed, for enhancement of resolution and depth.

As a known method of increasing the resolution of an optical microscope, there is a method (called "immersion method") in which the interspace between an objective lens and a sample is filled with a liquid of high refractive index (e.g. "Appl. Phys. Lett." 44652(1984), by D.W. Pohl, W. Denk & M. Lanz). The applicability of this method to transfer of fine circuit pattern of a semiconductor device is discussed in "Microelectronic Engineering" 9(1989), by H. Kawata, J.M. Carter, A. Yen and H.I. Smith, or in U.S. Patent No. 5,121,256 (T.R. Corle and G.S. Kino), June 9, 1992. Further, European Patent Application EP0,023,231A1 (Tabarelli, Werner W., Dr.) discloses a method in which a casing for immersion is placed on a stage movable in X, Y and Z directions and in which a wafer, a wafer chuck and a liquid are accommodated in the casing, the exposure operation being done while moving the casing.

However, use of an excimer laser, X-rays or electron beam leads to increased cost of the structure. Use of a phase shift mask or modified illumination involves a problem of ineffectiveness, depending on a circuit pattern used.

The paper by D.W. Pohl et al discusses the effect of immersion in exposure operation, but there is no men-

tion to the structure as a practical semiconductor exposure apparatus. Also, aforementioned U.S. Patent 5,121,256 mentions only a method wherein an immersed lens is disposed close to the wafer surface.

According to the method disclosed in the aforementioned European Patent Application 0,023,231, the weight of the moving components becomes large, and it results in decreased throughput (productivity). Although this European Patent Application further teaches connecting liquid circulation pipes to the casing for temperature control of the liquid, since the casing has to be moved, even use of a flexible material as the pipe material will adversely affect the stage positioning precision, particularly in consideration of current miniaturization of each semiconductor device.

It is accordingly an object of the present invention to provide an improved exposure apparatus low cost and high productivity, by which the effectiveness of a used exposure light source (such as g-line, i-line or excimer laser, for example) is assured regardless of the wavelength of the used light source.

The present invention provides a projection exposure apparatus, comprising:

- illumination means for illuminating a pattern of an original;
- holding means for holding a substrate;
- a projection optical system for projecting an image of the pattern of the original onto the substrate held by said holding means;

characterised in that:

- said projection optical system comprises a primary optical system and a secondary optical system separate from said primary optical system, said secondary optical system including a planar optical element to be positioned in a portion of a projection light path between said primary optical system and the substrate when the pattern of the original is projected on to the substrate through said projection optical system; and
- said apparatus further comprises a container adapted to be filled with a liquid material so as to be positioned between said optical element and the substrate when the pattern of the original is projected on to the substrate through said projection optical system wherein said optical element provides a cover member for said container.

In a preferred form, the apparatus may further comprise an alignment measuring system for detecting the positional relationship between the substrate and the image projected by the projection optical system with respect to a horizontal direction, a focus position detecting system for detecting the positional relationship between the substrate and the focus position of the projection optical system with respect to a vertical direction,

and tilt means for moving and/or tilting the holding means in X, Y and/or  $\theta$  direction on the basis of the detection through the alignment measuring system and the focus position detecting system so as to bring a pattern on the substrate into coincidence with the projected image. The apparatus may further comprise conveying means for loading and unloading the casing onto and from the holding means, and means for executing the filling of the interspace with the liquid, upon the holding means or at a position spaced from the holding means.

The substrate may provide a bottom of the casing, or the holding means may include a portion for directly supporting the substrate which portion is separated from the holding means, and wherein the portion provides a bottom of the casing while the remaining portion of the holding means holds the casing. In any case, the substrate is made detachable from the casing.

The casing may be arranged to provide one of a positive pressure and a negative pressure in the interspace. A portion of the casing may be made of a low thermal expansion material. A portion of the outer wall of the casing may be covered by a heat insulating material. The alignment measuring system may include a measurement reference mirror, wherein at least two adjoining faces of the outer wall of the casing may extend perpendicularly to each other, and wherein the at least two faces may extend substantially perpendicularly to the surface of the substrate whereby the reference mirror may be provided by the at least two faces.

The optical element may be made detachable from the casing. The casing may include pipe means with a valve, for injection and discharging of the liquid into and out of the closed space. The casing may have a reference mark to be used for placing the same on the holding means.

In relation to the liquid injected, the apparatus may comprise a pressure gauge for detecting the pressure of the filling liquid, pressure control means for controlling the pressure of the filling liquid, a vacuum pump for providing a negative pressure of the filling liquid, a thermometer for measuring the temperature of the filling liquid, temperature controlling means for controlling the temperature of the filling liquid, ultrasonic vibration means for vibrating the filling liquid with ultrasonics, a pump for injecting and discharging the liquid into and out of the closed space, filtering means coupled to the pump, for filtering the liquid, and attitude control means for tilting or holding the casing upright, wherein during injection of the liquid into the closed space the casing may be tilted or held upright so that the liquid is injected thereinto from below.

The injection of the liquid into the closed space and the exposure operation may be done at independent timings. The casing may be made openable and closable so as to allow loading and unloading of the substrate into and out of the inside of the casing. The holding means may include a passageway for holding the substrate through vacuum attraction, and an openable/clos-

able shutter for preventing flow of the liquid into the passageway. Measuring means may be provided in the casing, for measuring any non-uniformness of illuminance during the exposure operation. Further, the apparatus may be provided with means for providing at least one of electric connection, pneumatic communication and vacuum communication to the casing.

In one embodiment of the present invention, a portion of an objective lens constituting a projection optical system is provided on a side of a casing filled with liquid, and an original is moved together with this casing to an exposure station.

Alternatively, the conveyance of such casing and conveyance of a substrate as well as the filling of liquid may be executed at the exposure station. This needs a small modification of a projection exposure apparatus currently developed as a producing machine.

With the structure described above, the present invention utilizes the effect of immersion. Here, the term "effect of immersion" means that, if  $\lambda_0$  denotes the wavelength of exposure light in the air,  $n$  denotes the refractive index of liquid 23 with respect to the air, to be used for the immersion (see Figure 10), and  $\alpha$  denotes the convergence half angle of the light and if  $NA_0 = \sin \alpha$ , the resolution and the depth of focus described hereinbefore are represented as follows:

$$\text{Resolution} = k_1 (\lambda_0/n)/NA_0$$

$$\text{Depth of Focus} = \pm k_2 (\lambda_0/n)/(NA_0)^2$$

Namely, the effect of immersion is equivalent to use of an exposure wavelength of  $1/n$ . In other words, if a projection optical system of the same NA is designed, the immersion is able to enlarge the depth of focus  $n$  times. This is effective to any pattern, and it can be used in combination with the phase shift method or the modified illumination method. In order to assure this effect, it is necessary to control the purity, homogeneity or temperature of the liquid precisely. In an exposure apparatus of the type in which a wafer is sequentially exposed through step-and-repeat motion, it is important to minimize flow or vibration of the liquid during the exposure operation and to remove bubbles produced during immersion of a wafer in the liquid and remaining on the wafer surface.

With the present invention, an immersion type exposure apparatus which assures the effect of immersion sufficiently is provided. The present invention will enable use of a conventional stepper type exposure apparatus having an excimer laser light source or a conventional (established) manufacturing process, for the manufacture of DRAMs of 256 Mbit to 1 Gbit. Further, the present invention effectively the problem of contamination of a wafer, and it advantageously enhance the flatness correction of a wafer.

Embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a schematic side view of an immersion type projection exposure apparatus according to a first embodiment of the present invention.

Figure 2 is a schematic section of a cassette immersing operation device which can be incorporated into the apparatus of Figure 1.

Figure 3 is a sectional view of another type cassette usable in the apparatus of Figure 1.

Figure 4 is a schematic view of conveying means used in the immersing operation device of Figure 2.

Figure 5 is a schematic view of the structure for post-processing of a cassette, having been subjected to the exposure operation in the apparatus of Figure 1.

Figure 6 is a sectional view of a cassette chucking portion of an immersion type projection exposure apparatus according to a second embodiment of the present invention.

Figure 7 is a sectional view of a cassette chucking portion of an immersion type projection exposure apparatus according to a third embodiment of the present invention.

Figure 8 is a sectional view of a cassette chucking portion of an immersion type projection exposure apparatus according to a fourth embodiment of the present invention.

Figure 9 is a schematic view of an arrangement for adding an immersing operation device of a fifth embodiment of the present invention, to an exposure apparatus.

Figure 10 is a schematic view for explaining the effect of immersion.

#### Embodiment 1

Figure 1 is a schematic side view of an immersion type projection exposure apparatus according to a first embodiment of the present invention. In this apparatus, as illustrated, each wafer being accommodated and immersed in liquid in a cassette beforehand is conveyed for exposure of the same.

Denoted in the drawing at 1 is a reticle, and denoted at 3 is an illumination optical system having a shutter and a light adjusting device, etc. for projecting a circuit pattern of the reticle 1 upon a wafer having a photosensitive material coating. Denoted at 4 is a projection optical system for such pattern projection; at 5 is a reticle stage for holding and placing the reticle 1 at a predetermined position; and at 6 is an alignment optical system for providing correct alignment of an image of the reticle with a circuit pattern already printed on the wafer. Denoted at 7 is a lens of the projection optical system 4 which is disposed opposed to the surface of the wafer (hereinafter it will be called as "second optical element"). As shown in Figure 2, the second optical element 7 comprises a parallel plane glass. This is important in respect

to separating the second optical element 7 from the projection optical system 4 and to constituting a portion of a cassette 9 which is movable with a wafer stage. Also, making plane the surface of the optical element 7 opposed to the wafer 2 is important in the point of preventing an air layer or bubbles from being left at the surface of the second optical element 7 during immersing operation. Further, the surface of the optical element 7 and the surface of the photosensitive layer of the wafer, to be immersed, may desirably be coated with a material having affinity to the liquid used for the immersion. Also, as shown in Figure 2, a seal 8 is provided between the second optical element 7, the wafer 2 and the cassette 9 to prevent leakage of liquid 23 and to assure tightness of the cassette 9.

Denoted at 10 is a cassette stock for storing the cassette 9 therein. Denoted at 11-1 to 11-3 are (components of) a cassette conveying device and a cassette rough-positioning device, for taking the cassette 9 out of the stock 10 and moving the same onto the wafer stage. More specifically, reference numeral 11-1 denotes a cassette conveying device for conveying the cassette 9 and reference numeral 11-2 denotes a cassette position rough-detection mechanism (usually called "prealignment mechanism"). Reference numeral 11-3 denotes a hand for feeding the cassette 9. Denoted at 12 is a wafer chuck for holding the wafer (mounted on the bottom of the cassette 9) together with the cassette. Denoted at 13 is an X-Y stage for positioning the wafer (in the cassette 9) at a predetermined position. Denoted at 14 is a fine-motion stage having a wafer  $\theta$ -position correcting function, a wafer Z-position adjusting function and a tilt function for correcting any tilt of the wafer. Denoted at 15 is laser interferometer means for measuring the position of the stage. Denoted at 16 is a reference mirror which is mounted on the top of the fine-motion stage 14 in respect to the X direction (another, not shown, is mounted in respect to the Y direction), for reflecting light from the laser interferometer means 15.

Mounted around the cassette 9 is a heat insulating material 17 for blocking heat transfer to the outside so as to keep the temperature. The heat insulating material 17 may be omitted if the cassette 9 itself is made of a material having a heat insulating effect, such as engineering ceramics, for example. Also, the cassette 9 may be made of a low thermal expansion material such as Celodur or Superinvar (tradename) and the reference mirror 16 of the laser interferometer means 16 may be mounted on the side face of it, with a result of enhanced measurement precision. Further, in that occasion, even if a foreign particle is adhered to the surface of the second optical element 7 which is mounted on the top of the cassette 9 and at a position spaced from the wafer surface, it is not easily transferred to the wafer surface. Thus, the problem of particle adhesion to the wafer surface or contamination of the same during the wafer conveyance, can be solved. This is very effective to the manufacture of semiconductor devices of decreasing

linewidths.

For exposure operation, first a cassette 9 in which a wafer 2 having a photosensitive material is mounted and the inside of which is filled with a liquid 23, such as shown in Figure 2, is taken out of the stock 10 by using the cassette conveying device 11-1. It is then placed on the cassette position rough detection mechanism 11-2 and, after prealignment operation, the cassette 9 is handled by the hand 11-3 and moved onto the wafer chuck 12 of the wafer stage. Then, its position is adjusted and it is held thereat by attraction. Subsequently, like the operation in an ordinary wafer exposure apparatus, the fine positioning operation to the wafer 2 (alignment operation, focusing operation, etc.) is done and, thereafter, the exposure operation is done. Here, there may occur flow motion of the liquid 23 with the step-and-repeat motion. Since however the spacing between the surfaces of the second optical element 7 and the wafer 2 is small, such as of an order of a few millimeters to several tens millimeters and since the liquid 23 has viscosity, such motion of the liquid 23 in the cassette 9 is attenuated in a relatively short time period. Since the outside peripheral surface of the cassette 9 is covered by a heat insulating material, a constant temperature can be maintained at least during a period of processing one wafer. Thus, no temperature control may be necessary. After the whole surface of the wafer 2 is completed, the cassette 9 placed on the wafer chuck 12 is handled by an unloading hand 11-4 and it is moved into another cassette stock 10.

Figure 2 is a schematic section of a cassette immersing operation device for mounting a wafer 2 in a cassette 9 while a negative pressure is provided within the cassette 9 and for filling the inside of the cassette 9 with a liquid 23. Figure 3 is a sectional view which illustrates a case where a wafer 2 is mounted in a cassette 9 while a positive pressure is provided within the cassette. Such device may be incorporated into the projection exposure apparatus for wafer processing.

As seen in Figure 2, the cassette immersing operation device comprises a thermometer 18 for measuring temperature of the liquid 23; a temperature controller for adjusting the liquid 23 temperature on the basis of the output of the thermometer; a circulation pump 20 for controlling the quantity of the liquid 23 and for circulating the temperature controlled liquid 23 as well as for controlling the pressure of the liquid 23; a filter 21 for filtering impurities of the liquid 23; an ultrasonic vibration device 22 which is provided to homogenize the liquid 23 and to prevent adhesion of bubbles to the surface of the wafer 2 or the second optical element 7; a vacuum pump 24 for providing a negative pressure within the cassette to remove bubbles in the liquid 23; a valve 25-1 connected to the vacuum pump 24; valves 25-2 and 25-3 connected to the piping system of the liquid 23; a fixture element 26 for fixing the second optical element 7; and a pressure gauge 27 for measuring the inside pressure of the cassette 9.

Figure 4 is a schematic view of conveying means used in this cassette immersing operation device. In Figure 4, denoted at 28 is a wafer stock and denoted at 29 is a wafer loading hand for taking a wafer out of the wafer stock 28 and for moving it into a wafer rough positioning device 30. Denoted at 31 is a cassette loading hand for taking a cassette 9 out of the cassette stock 10 and for moving it to a predetermined position, and denoted at 32 is a cassette station which includes a wafer chuck for fixing a wafer 2 and a cassette chuck for fixing the cassette 9 and for automatically connecting pipes and sensors to the cassette 9. Denoted at 33 is a mechanism for tilting the cassette station 32, and denoted at 34 is a wafer moving hand for moving the positioned wafer 2 onto the wafer chuck 112.

Figure 5 is a schematic view, illustrating the post-processing of the cassette 9 having been subjected to the exposure operation. Denoted in the drawing at 36 is a post-processing station having a mechanism for unloading the liquid 23 in the cassette having been subjected to the exposure operation. Denoted at 35 is a cassette unloading hand for moving the cassette 9 to the post-processing station 36, and denoted at 38 is another hand for taking the wafer 2 out of the cassette 9 and for conveying the same to a wafer stock 28. Denoted at 39 is a hand for moving the empty cassette 9 back into the cassette stock 10.

In the immersing operation, as shown in Figure 4, first a wafer 2 having a photosensitive material coating is taken out of the wafer stock 28 by means of a wafer loading hand 29, and it is placed on a wafer rough positioning device 30 for rough positioning of the same. The thus positioned wafer 2 is moved and positioned on the wafer chuck of the cassette station 32 by means of the wafer moving hand 34. The wafer is then held thereon by vacuum attraction. Subsequently, an empty cassette is taken out of the cassette stock 10 by means of the cassette conveying hand 31, and it is placed on the wafer chuck 112 of the cassette station 32. In this state, various pipes and sensors are coupled to the wafer chuck 112 of the cassette station 32 through the wafer chuck 112, for example. By this, the wafer 2 is positioned on the bottom of the cassette 9. Thereafter, the mechanism 33 is actuated to tilt the cassette 9 or hold it upright, together with the cassette station 32. Then, the circulation pump 20 is actuated to pump the liquid 23 into the cassette 9 until predetermined quantity of liquid is fed therein. Then, the pump 20 stops.

Here, there is a possibility that a small air remains in the upper portion of the wafer cassette 9. In consideration thereof, the vacuum pump 24 is connected to such portion. Thus, by operating the vacuum pump 24, any air remaining in the liquid 23 can be removed. In that occasion, the ultrasonic vibration device 22 may be operated, by which small bubbles adhered to the inside wall of the cassette 9 or to the surface of the wafer 2 can be removed. This assures homogenization of the liquid 23 in a reduced time. After the remaining air in the cas-

sette 9 is removed, a vacuum pump valve 25-1 incorporated in the cassette 9 is closed, and the circulation pump 20 is actuated again so as to fill the inside of the cassette 9 with the liquid 23. The inside pressure is decreased by a small amount while it is monitored by means of the pressure gauge 27. The amount of pressure decrease for fixation of the wafer 2 on the bottom of the cassette 9 may be sufficiently of an order of 0.99 - 0.80 times the atmospheric pressure. When the inside pressure becomes equal to a predetermined level, the circulation pump 20 is stopped and valves 25-2 and 25-3 provided in respective pipes of the cassette 9 are closed. In this state, the cassette station 32 is moved back to its horizontal attitude, and the cassette having its immersing operation now completed is moved back into the cassette stock 10 by means of the conveying hand 31.

The above-described operation is repeated, and the wafer 2 is set in the immersed state. When this device is incorporated into the exposure apparatus of Figure 1, the immersed cassette 9 may be directly conveyed onto the wafer chuck 12 of the wafer stage by means of the cassette loading hand 11-3. In that case, the cassette conveying device 11-1 and the cassette position detecting mechanism 11-2 of Figure 1 may be substituted by the cassette loading hand 31 and the cassette station 32.

For collection of a cassette having been subjected to the exposure operation, the cassette unloading hand 35 is used in place of the unloading hand 11-4 of Figure 1. That is, the cassette is placed on the post-processing station 36 and, after the liquid 23 is removed by means of the liquid removing mechanism, the cassette 9 is opened by using the hand 38 and the wafer 2 therein is taken out of the cassette and is moved into the wafer stock 28. The empty cassette is moved back into the cassette stock 10 by the hand 39.

The arrangement of Figures 2 - 5 may be structured into an independent mechanism, separate of the exposure apparatus of Figure 1. Also, in the described example, when the liquid 23 is flown into the cassette 9, the cassette is held inclined or held upright and the liquid is discharged into the cassette from below. This is effective to avoid bubbles remaining inside the cassette. Also, for removing any bubbles in the liquid, the ultrasonic vibration device 22 and the vacuum pump 24 are used, this being effective to prevent any bubbles from remaining in the liquid/cassette. Further, it is possible that, after the wafer 2 is unloaded from the cassette 9 placed at the post-processing station 36, an air-blow device 40 is used to dry the wafer 2.

#### Embodiment 2

Figure 6 is a sectional view of a cassette chucking portion of an immersion type projection exposure apparatus according to a second embodiment of the present invention. In this apparatus, a wafer chuck 601 is pro-

vided in a cassette 9, and a cassette chuck 612 for positioning and holding the cassette 9 through vacuum attraction is disposed on a fine motion stage 14 (Figure 1), in place of the wafer chuck 12 of Figure 1. In this example, the cassette 9 has an opening/closing mechanism 631 for allowing loading/unloading of the wafer 2. Thus, the second optical element 7 is made detachable. Further, the cassette chuck 612 has positioning pins 617, for positioning the cassette 9, which are embedded at three locations. The remaining structure is essentially the same as that of the Figure 1 apparatus, and the exposure operation is made similarly by using the cassette having been immersed preparatorily.

#### Embodiment 3

Figure 7 is a sectional view of a cassette chucking portion of an immersion type projection exposure apparatus according to a third embodiment of the present invention. In this apparatus, the bottom of the cassette 9 provides a wafer chuck 601, such that the wafer chuck 601 can be separated from the main portion of the cassette 9. This separability allows loading/unloading of a wafer 2. The remaining structure is essentially the same as that of the Figure 6 apparatus.

#### Embodiment 4

Figure 8 is a sectional view of a cassette chucking portion of an immersion type projection exposure apparatus according to a fourth embodiment of the present invention. In this apparatus, after a cassette 9 is conveyed to and held on a cassette chuck 612, the immersing operation is done. In Figure 8, denoted at 801 is a liquid level gauge for measuring the level of liquid 23 in the cassette 9, and denoted at 803 is a measuring device for measuring the refractive index of the liquid 23. Denoted at 805 is a connector for electrically connecting the cassette 9 with the cassette chuck 612; denoted at 807 is a valve coupled to a vacuum pump 24; denoted at 601 is a wafer chuck which defines the bottom of the cassette 9 and which can be separated from the main assembly of the cassette 9; denoted at 631 is an opening/closing mechanism for separating the wafer chuck 601 for unloading/loading the wafer 2. Like numerals as of those of the preceding drawings are assigned to similar elements.

In the structure of this embodiment, the cassette 9 is conveyed onto the cassette chuck 612 in a similar manner as of the embodiment of Figure 1, and it is positioned and held fixed through vacuum attraction. In response, the cassette 9 and the cassette chuck 612 are coupled to each other. At the same time, various sensors and pipes from a vacuum pump 24, a circulation pump 20 and so on are automatically connected to the cassette. The liquid 23 for immersion having its temperature controlled by a temperature controller 19 is pumped by the circulation pump into the cassette 9

through a filter 21. When the liquid 23 of a predetermined quantity is fed, this is detected by the liquid level gauge 801 and the pump 20 is stopped.

Subsequently, the vacuum pump 24 coupled to a portion adjacent to the top of the cassette 9 is actuated to remove bubbles in the liquid 23. Simultaneously, an ultrasonic vibration device 22 is actuated to remove bubbles in the liquid 23, bubbles adhered to the wafer 2 surface, and bubbles adhered to the surface of the second optical element 7. Such ultrasonic vibration is effective also for homogenization of the liquid 23 itself. Since the amplitude of vibration is so small and the frequency is high, it does not affect the wafer positioning or wafer exposure.

After the bubbles are removed, the vacuum pump 24 is stopped and the valve 87 is closed. Also, the pressurizing and circulating pump 20 is actuated to start pressurization of the liquid 23. When a pressure gauge 27 detects the attainment of a predetermined pressure, continuous monitoring of the temperature of the liquid 23 through a thermometer 18 starts. If the temperature shifts from a predetermined temperature, the pressurizing and circulating pump 20 is actuated again to circulate liquid 23 of constant temperature. Here, the circulation of liquid 23 produces flow motion of the same, and it disturbs the homogeneity of the liquid 23. In consideration thereof, the refractometer 803 is used to measure the homogeneity of the liquid. The exposure operation is done after the homogeneity is checked.

The exposure operation is done in a similar manner as described. In order to prevent any effect of motion of the liquid 23 resulting from step-and-repeat motion, a delay time may be set after the stepwise motion for each shot. Alternatively, the state of flow motion may be measured by using the refractometer 803, and the sequence may be continued after the liquid motion stops. Further, the pressure of the liquid 23 may be used to enhance the function of the wafer chuck 601 for correcting flatness of the wafer 2.

After the exposure operation is completed, the circulation pump 20 is actuated to discharge the liquid 23 out of the cassette. Then, the shutter inside the wafer chuck 601 is closed and, after this, the cassette 9 is moved back into the stock 10. By this, the exposure process of one wafer is completed.

#### Embodiment 5

Figure 9 is a schematic view of a structure which is adapted to add an immersing operation device of a fifth embodiment of the present invention, to an exposure apparatus. This structure is applicable to the arrangement of Figure 6 or 7 wherein a cassette of wafer accommodation type is used. This example differs from the Figure 4 embodiment in the points that a cassette hand 901 having a cassette opening/closing mechanism is used in place of the cassette hand 31, that a cassette chuck 903 is used in place of the wafer chuck

112 and that the hand is arranged to move a wafer into a cassette 9 held on the cassette chuck 903.

With this arrangement, for immersion, first an empty cassette is taken out of a cassette stock 10 by means of the cassette hand 901, and it is placed on the cassette chuck 903. In this state, various pipes and sensors are connected to the cassette, as in the case of Figure 8. Simultaneously, the cassette 9 is opened by means of the opening/closing mechanism, and a wafer 2 having a photosensitive material coating is taken out of a wafer stock 28 by means of the hand 29. The wafer is then placed on a wafer rough positioning mechanism 30, and rough positioning of the same is done. The thus positioned wafer is then placed and positioned on the wafer chuck in the cassette 9 by means of the hand 34, and it is held fixed through vacuum attraction. Subsequently, the cassette 9 is closed by the cassette hand 901 and it is locked. After this, the cassette 9 is tilted or held upright together with the cassette station 32. Thereafter, the liquid 23 is fed into the cassette 9 in a similar manner as described, and bubbles in the liquid 23 are removed. Then, the liquid is pressurized. After a predetermined pressure is attained, the circulation pump is stopped, and the valves in the pipes incorporated into the cassette are closed. Then, the cassette station 32 is moved back to its horizontal attitude, and the cassette 9 having its immersing operation completed is moved back into the cassette stock 10 by means of the cassette hand 901.

Also in this example, the device can be incorporated into the exposure apparatus of Figure 1 in a similar manner as has been described with reference to Figure 4. Further, the post-processing after the exposure operation may be done in a similar manner as has been described with reference to Figure 5.

While the invention has been described with reference to the structures disclosed herein, it is not confined to the details set forth and this application is intended to cover such modifications or changes as may come within the scope of the following claims.

#### Claims

1. A projection exposure apparatus, comprising:

illumination means (3) for illuminating a pattern of an original (1);  
holding means (12) for holding a substrate (2);  
a projection optical system (4, 7) for projecting an image of the pattern of the original (1) onto the substrate (2) held by said holding means (12);

characterised in that:

said projection optical system (4, 7) comprises a primary optical system (4) and a secondary

- optical system (7) separate from said primary optical system (4), said secondary optical system (7) including a planar optical element (7) to be positioned in a portion of a projection light path between said primary optical system (4) and the substrate (2) when the pattern of the original (1) is projected on to the substrate (2) through said projection optical system (4, 7); and
- said apparatus further comprises a container (9) adapted to be filled with a liquid material (23) so as to be positioned between said optical element (7) and the substrate (2) when the pattern of the original (1) is projected on to the substrate (2) through said projection optical system (4, 7) wherein said optical element (7) provides a cover member for said container (9).
2. An apparatus according to claim 1, further comprising an alignment measuring system (6, 16) for detecting the positional relationship between the substrate (2) and the image projected by said projection optical system (4, 7) with respect to a horizontal direction, a focus position detecting system for detecting the positional relationship between the substrate and the focus position of said projection optical system (4, 7) with respect to a vertical direction, and tilt means for moving and/or tilting said holding means in X, Y and/or  $\theta$  direction on the basis of the detection through said alignment measuring system and the focus position detecting system so as to bring a pattern on the substrate into coincidence with the projected image.
  3. An apparatus according to claim 1, further comprising conveying means (11-4) for loading and unloading said container (9) onto and from said holding means (12).
  4. An apparatus according to claim 3, further comprising means (20, 21) for executing the filling of the container (9) with the liquid (23), upon said holding means (12).
  5. An apparatus according to claim 3, further comprising means for executing the filling of the container (9) with the liquid (23), at a position spaced from said holding means (12).
  6. An apparatus according to claim 3, wherein the substrate (2) provides a base of said container (9).
  7. An apparatus according to claim 1, wherein said holding means (12) includes a portion for directly supporting the substrate (2) which portion is separated from said holding means (12), and wherein said portion provides a base of said container (9) while the remaining portion of said holding means holds said container (9).
  8. An apparatus according to claim 6, wherein the substrate (2) is detachable from said container (9).
  9. An apparatus according to claim 1, wherein said container (9) is arranged to provide one of a positive pressure and a negative pressure therein.
  10. An apparatus according to claim 1, wherein a portion of said container (9) is made of a low thermal expansion material.
  11. An apparatus according to claim 1, wherein a portion of the outer wall of said container (9) is covered by a heat insulating material.
  12. An apparatus according to claim 2, wherein said alignment measuring system (6, 16) includes a measurement reference mirror (16), wherein at least two adjoining faces of the outer wall of said container (9) extend perpendicularly to each other, and wherein said at least two faces extend substantially perpendicularly to the surface of the substrate (2) whereby said reference mirror (16) is provided by said at least two faces.
  13. An apparatus according to claim 1, wherein said optical element (7) is detachable from said container (9).
  14. An apparatus according to claim 1, wherein said container (9) includes pipe means with a valve (25-3), for injection and discharging of the liquid into and out of said container (9).
  15. An apparatus according to claim 1, wherein said container (9) has a reference mark to be used for placing the same on said holding means (12).
  16. An apparatus according to claim 1, further comprising a pressure gauge (27) for detecting the pressure of the liquid material in said container (9).
  17. An apparatus according to claim 1, further comprising pressure control means for controlling the pressure of the filling liquid.
  18. An apparatus according to claim 1, further comprising a vacuum pump for providing a negative pressure of the liquid material in said container (9).
  19. An apparatus according to claim 1, further comprising a thermometer (18) for measuring the temperature of the liquid material in said container (9).
  20. An apparatus according to claim 1, further comprising temperature controlling means for controlling



the temperature of the liquid material in said container (9).

21. An apparatus according to claim 1, further comprising ultrasonic vibration means (22) for vibrating the liquid material in said container (9) with ultrasonic vibrations. 5
22. An apparatus according to claim 1, further comprising a pump (20) for injecting and discharging the liquid into and out of the container (9). 10
23. An apparatus according to claim 22, further comprising filtering means (21) coupled to said pump (20), for filtering the liquid. 15
24. An apparatus according to claim 1, further comprising attitude control means for tilting or holding said container (9) upright, wherein during injection of the liquid into the container (9) said container (9) is tilted or held upright so that the liquid is injected thereinto from below. 20
25. An apparatus according to claim 5, wherein the injection of the liquid into the container (9) and the exposure operation are done at independent timings. 25
26. An apparatus according to claim 1, wherein said container (9) is openable and closable so as to allow loading and unloading of the substrate (2) into and out of the inside of said container (9). 30
27. An apparatus according to claim 7, wherein said holding means (12) includes a passageway for holding the substrate (2) through vacuum attraction, and an openable/closable shutter for preventing flow of the liquid into said passageway. 35
28. An apparatus according to claim 1, further comprising measuring means provided in said container (9), for measuring any non-uniformness of illuminance during the exposure operation. 40
29. An apparatus according to claim 7, wherein said container (9) has a member operable as a reference in respect to the positioning on another portion of said holding means (12). 45
30. An apparatus according to claim 1, further comprising means for providing at least one of electric connection, pneumatic communication and vacuum communication to said container (9). 50
31. An apparatus according to claim 1, further comprising means for measuring the refractive index of the liquid material in said container (9). 55

## Patentansprüche

### 1. Projektionsbelichtungsgerät mit:

einer Beleuchtungseinrichtung (3) zum Beleuchten eines Musters von einem Original (1), einer Halteeinrichtung (12) zum Halten eines Substrates (2), einem optischen Projektionssystem (4, 7) zum Projizieren eines Bildes von einem Muster des Originalen (1) auf das Substrat (2), daß durch die Halteeinrichtung (12) gehalten wird,

### dadurch gekennzeichnet, daß

das optische Projektionssystem (4, 7) ein erstes optisches System (4) und ein zweites optisches System (7), das von dem ersten optischen System (4) getrennt ist, aufweist, wobei das zweite optische System (7) ein ebenes optisches Element (7) umfaßt, das in einem Abschnitt einer Projektionslichtbahn zwischen dem ersten optischen System (4) und dem Substrat (2) zu positionieren ist, wenn das Muster des Originalen (1) auf das Substrat (2) durch das optische Projektionssystem (4, 7) projiziert wird, und das Gerät des weiteren einen Behälter (9) aufweist, der darein angepaßt ist, daß er mit einem Flüssigkeitsmaterial (23) gefüllt wird, um so zwischen dem optischen Element (7) und dem Substrat (2) positioniert zu werden, wenn das Muster des Originalen (1) auf das Substrat (2) durch das optische Projektionssystem (4, 7) projiziert wird, wobei das optische Element (7) ein Abdeckelement für den Behälter (9) vorsieht.

### 2. Gerät gemäß Anspruch 1, das des weiteren folgende Bauteile aufweist:

ein Ausrichtungsmeßsystem (6, 16) zum Erfassen der Positionsbeziehung zwischen dem Substrat (2) und dem Bild, das durch das optische Projektionssystem (4, 7), in Bezug auf eine horizontale Richtung projiziert wurde, ein Brennpunktpositionserfassungssystem zum Erfassen der Positionsbeziehung zwischen dem Substrat und der Brennpunktposition des optischen Projektionssystems (4, 7) in Bezug auf eine vertikale Richtung, und eine Neigungseinrichtung zum Bewegen und / oder Neigen der Halteeinrichtung in die Richtung X, Y, und / oder  $\theta$  auf der Grundlage der Erfassung durch das Ausrichtungsmeßsystem und das Brennpunktpositionserfassungssystem, um ein Muster auf dem Substrat mit dem projizierten Bild in Übereinstimmung zu

bringen.

3. Gerät gemäß Anspruch 1, das des weiteren eine Fördereinrichtung (11-4) zum Beladen und Entladen des Behälters (9) auf die Halteeinrichtung (12) bzw. von dieser aufweist.
4. Gerät gemäß Anspruch 3, das des weiteren eine Einrichtung (20, 21) zum Ausführen des Füllens des Behälters (9) mit der Flüssigkeit (23) auf der Halteeinrichtung (12) aufweist.
5. Gerät gemäß Anspruch 3, das des weiteren eine Einrichtung zum Ausführen des Füllens des Behälters (9) mit der Flüssigkeit (23) an einer von der Halteeinrichtung (12) beabstandeten Position aufweist.
6. Gerät gemäß Anspruch 3, wobei das Substrat (2) ein Grundelement des Behälters (9) vorsieht.
7. Gerät gemäß Anspruch 1, wobei die Halteeinrichtung (12) einen Abschnitt zum direkten Stützen des Substrates (2) umfaßt, wobei dieser Abschnitt von der Halteeinrichtung (12) getrennt ist und wobei dieser Abschnitt ein Grundelement des Behälters (9) vorsieht, während der restliche Abschnitt der Halteeinrichtung den Behälter (9) hält.
8. Gerät gemäß Anspruch 6, wobei das Substrat (2) von dem Behälter (9) abnehmbar ist.
9. Gerät gemäß Anspruch 1, wobei der Behälter (9) so eingerichtet ist, daß in ihm entweder ein Überdruck oder ein Unterdruck vorgesehen ist.
10. Gerät gemäß Anspruch 1, wobei ein Abschnitt des Behälters (9) aus einem Material mit einer geringen Wärmeausdehnung hergestellt ist.
11. Gerät gemäß Anspruch 1, wobei ein Abschnitt der Außenwand des Behälters (9) mit einem Wärmeisolationsmaterial bedeckt ist.
12. Gerät gemäß Anspruch 2, wobei das Ausrichtungsmeßsystem (6, 16) einen Meßbezugsspiegel (16) umfaßt, wobei zumindest zwei angrenzende Seiten der Außenwand von dem Behälter (9) sich senkrecht zueinander erstrecken und wobei die zumindest beiden Seiten sich senkrecht zu der Oberfläche des Substrates (2) erstrecken, wodurch der Bezugsspiegel (16) durch diese zumindest zwei Seiten vorgesehen wird.
13. Gerät gemäß Anspruch 1, wobei das optische Element (7) von dem Behälter (9) abnehmbar ist.
14. Gerät gemäß Anspruch 1, wobei der Behälter (9) eine Rohreinrichtung mit einem Ventil (25-3) für ein Einspritzen und Herauslassen der Flüssigkeit in den Behälter (9) und aus ihm heraus umfaßt.
15. Gerät gemäß Anspruch 1, wobei der Behälter (9) eine Bezugsmarkierung hat, die zum Anordnen des Behälters auf der Halteeinrichtung (12) verwendet wird.
16. Gerät gemäß Anspruch 1, das des weiteren eine Druckmeßeinrichtung (27) zum Erfassen des Druckes des Flüssigkeitsmaterials in dem Behälter (9) aufweist.
17. Gerät gemäß Anspruch 1, das des weiteren eine Drucksteuereinrichtung zum Steuern des Druckes der Füllflüssigkeit aufweist.
18. Gerät gemäß Anspruch 1, das des weiteren eine Unterdruckpumpe zum Vorsehen eines Unterdruckes in dem Flüssigkeitsmaterial in dem Behälter (9) aufweist.
19. Gerät gemäß Anspruch 1, das des weiteren ein Thermometer (18) zum Messen der Temperatur des Flüssigkeitsmaterials in dem Behälter (9) aufweist.
20. Gerät gemäß Anspruch 1, das des weiteren eine Temperatusteuerereinrichtung zum Steuern der Temperatur des Flüssigkeitsmaterials in dem Behälter (9) aufweist.
21. Gerät gemäß Anspruch 1, das des weiteren eine Ultraschallschwingungseinrichtung (22) zum in Schwingungversetzen des Flüssigkeitsmaterials in dem Behälter (9) mit Ultraschallschwingungen aufweist.
22. Gerät gemäß Anspruch 1, das des weiteren eine Pumpe (20) zum Einspritzen und Herauslassen der Flüssigkeit in den Behälter (9) und aus ihm heraus aufweist.
23. Gerät gemäß Anspruch 22, das des weiteren eine Filtereinrichtung (21), die mit der Pumpe (20) gekoppelt ist, zum Filtern der Flüssigkeit aufweist.
24. Gerät gemäß Anspruch 1, das des weiteren eine Stellungssteuereinrichtung zum Neigen des Behälters oder zum Aufrechterhalten des Behälters (9) aufweist, wobei während des Einspritzens der Flüssigkeit in den Behälter (9) der Behälter (9) geneigt oder

aufrecht gehalten wird, so daß die Flüssigkeit in diesen hinein von unten eingespritzt wird.

25. Gerät gemäß Anspruch 5, wobei das Einspritzen der Flüssigkeit in den Behälter (9) und der Belichtungsvorgang zeitlich unabhängig ausgeführt werden. 5
26. Gerät gemäß Anspruch 1, wobei der Behälter (9) offenbar und schließbar ist, so daß ein Beladen und Entladen des Substrates (2) in das Innere des Behälters (9) und aus diesem heraus ermöglicht ist. 10
27. Gerät gemäß Anspruch 7, wobei die Halteeinrichtung (12) einen Durchtritt zum Halten des Substrates (2) durch ein Vakuumanziehen und einenöffnungsfähigen / schließfähigen Verschluß zum Verhindern eines Strömens der Flüssigkeit in den Durchtritt hinein umfaßt. 15 20
28. Gerät gemäß Anspruch 1, das des weiteren eine Meßeinrichtung, die in dem Behälter (9) vorgesehen ist, zum Messen jeglicher Ungleichmäßigkeit der Beluchtungsstärke während des Belichtungsvorganges aufweist. 25
29. Gerät gemäß Anspruch 7, wobei der Behälter (9) ein Element hat, das als ein Bezug im Hinblick auf das Positionieren an einem anderen Abschnitt der Halteeinrichtung (12) betreibbar ist. 30
30. Gerät gemäß Anspruch 1, das des weiteren eine Einrichtung zum Vorsehen von zumindest entweder einem elektrischen Anschluß, einer pneumatischen Verbindung oder einer Unterdruckverbindung zu dem Behälter (9) aufweist. 35
31. Gerät gemäß Anspruch 1, das des weiteren eine Einrichtung zum Messen des Brechungsindex des Flüssigkeitsmaterials in dem Behälter (9) aufweist. 40

#### Revendications

1. Appareil d'exposition par projection, comprenant :  
des moyens d'éclairage (3) pour éclairer un motif d'un original (1) ;  
des moyens de maintien (12) pour maintenir un substrat (2) ;  
un système optique de projection (4, 7) pour projeter une image du motif de l'original (1) sur le substrat (2) maintenu par lesdits moyens de maintien (12) ; 50 55

caractérisé en ce que

ledit système optique de projection (4, 7) comprend un système optique primaire (4) et un système optique secondaire (7) séparé dudit système optique primaire (4), ledit système optique secondaire (7) comportant un élément optique plan (7) devant être positionné dans une partie d'un chemin optique de projection entre ledit système optique primaire (4) et le substrat (2) lorsque le motif de l'original (1) est projeté sur le substrat (2) à travers ledit système optique de projection (4, 7) ; et  
ledit appareil comprend en outre un récipient (9) conçu pour être rempli d'une matière liquide (23) de façon à être positionné entre ledit élément optique (7) et le substrat (2) lorsque le motif de l'original (1) est projeté sur le substrat (2) à travers ledit système optique de projection (4, 7), dans lequel ledit élément optique (7) constitue un élément formant capuchon pour ledit récipient (9).

2. Appareil selon la revendication 1, comprenant en outre un système de mesure d'alignement (6, 16) pour détecter la relation de position entre le substrat (2) et l'image projetée par ledit système optique de projection (4, 7) par rapport à une direction horizontale, un système de détection de position de foyer pour détecter la relation de position entre le substrat et la position du foyer dudit système optique de projection (4, 7) par rapport à une direction verticale, et des moyens d'inclinaison pour déplacer et/ou incliner lesdits moyens de maintien dans une direction X, Y et/ou  $\theta$  sur la base de la détection effectuée au moyen dudit système de mesure d'alignement et dudit système de détection de position de foyer de façon à faire coïncider un motif sur le substrat avec l'image projetée.
3. Appareil selon la revendication 1, comprenant en outre des moyens de transport (11-4) pour charger et décharger ledit récipient (9) sur et depuis lesdits moyens de maintien (12). 45
4. Appareil selon la revendication 3, comprenant en outre des moyens (20, 21) pour réaliser le remplissage du récipient (9) avec le liquide (23), sur lesdits moyens de maintien (12).
5. Appareil selon la revendication 3, comprenant en outre des moyens pour réaliser le remplissage du récipient (9) avec le liquide (23), à une position espacée desdits moyens de maintien (12).
6. Appareil selon la revendication 3, dans lequel le substrat (2) constitue une base dudit récipient (9).

7. Appareil selon la revendication 1, dans lequel lesdits moyens de maintien (12) comportent une partie destinée à supporter directement le substrat (2), cette partie étant séparée desdits moyens de maintien (12) et dans lequel ladite partie constitue une base dudit récipient (9) tandis que la partie restante desdits moyens de maintien maintient ledit récipient (9).
8. Appareil selon la revendication 6, dans lequel le substrat (2) est démontable dudit récipient (9).
9. Appareil selon la revendication 1, dans lequel ledit récipient (9) est conçu pour produire l'une d'une pression positive et d'une pression négative dans celui-ci.
10. Appareil selon la revendication 1, dans lequel une partie dudit récipient (9) est faite d'un matériau à faible dilatation thermique.
11. Appareil selon la revendication 1, dans lequel une partie de la paroi extérieure dudit récipient (9) est recouverte d'un matériau thermiquement isolant.
12. Appareil selon la revendication 2, dans lequel ledit système de mesure d'alignement (6, 16) comporte un miroir de référence de mesure (16), dans lequel au moins deux faces jointives de ladite paroi extérieure dudit récipient (9) s'étendent perpendiculairement l'une à l'autre, et dans lequel lesdites au moins deux faces s'étendent sensiblement perpendiculairement à la surface du substrat (2). ledit miroir de référence (16) étant constitué par lesdites au moins deux faces.
13. Appareil selon la revendication 1, dans lequel ledit élément optique (7) est démontable dudit récipient (9).
14. Appareil selon la revendication 1, dans lequel ledit récipient (9) comprend des moyens à canalisation ayant une vanne (25-3) pour l'injection et l'expulsion du liquide vers l'intérieur et en dehors dudit récipient (9).
15. Appareil selon la revendication 1, dans lequel ledit récipient (9) présente un repère de référence devant être utilisé pour mettre en place ce dernier sur lesdits moyens de maintien (12).
16. Appareil selon la revendication 1, comprenant en outre un manomètre (27) pour détecter la pression de la matière liquide dans ledit récipient (9).
17. Appareil selon la revendication 1, comprenant en outre des moyens de commande de pression pour commander la pression du liquide de remplissage.
18. Appareil selon la revendication 1, comprenant en outre une pompe à vide pour produire une pression négative de la matière liquide dans ledit récipient (9).
19. Appareil selon la revendication 1, comprenant en outre un thermomètre (18) pour mesurer la température de la matière liquide dans ledit récipient (9).
20. Appareil selon la revendication 1, comprenant en outre des moyens de commande de température pour commander la température de la matière liquide dans ledit récipient (9).
21. Appareil selon la revendication 1, comprenant en outre des moyens générateurs de vibration ultrasonore (22) pour faire vibrer la matière liquide dans ledit récipient (9) avec des vibrations ultrasonores.
22. Appareil selon la revendication 1, comprenant en outre une pompe (20) pour l'injection et l'expulsion du liquide vers l'intérieur et en dehors du récipient (9).
23. Appareil selon la revendication 22, comprenant en outre des moyens de filtrage (21) couplés à ladite pompe (20), pour filtrer le liquide.
24. Appareil selon la revendication 1, comprenant en outre des moyens de commande d'attitude pour incliner ou maintenir ledit récipient (9) verticalement, dans lequel pendant l'injection du liquide dans le récipient (9), ledit récipient (9) est incliné ou maintenu verticalement de façon que le liquide soit injecté dans celui-ci par le bas.
25. Appareil selon la revendication 5, dans lequel l'injection du liquide dans le récipient (9) et l'opération d'exposition sont effectuées à des instants indépendants.
26. Appareil selon la revendication 1, dans lequel ledit récipient (9) peut être ouvert et fermé de façon à permettre le chargement et le déchargement du substrat (2) à l'intérieur et hors du récipient (9).
27. Appareil selon la revendication 7, dans lequel lesdits moyens de maintien (12) comportent un passage pour maintenir le substrat (2) par attraction par aspiration et un obturateur pouvant être ouvert/fermé pour empêcher un écoulement du liquide dans ledit passage.
28. Appareil selon la revendication 1, comprenant en outre des moyens de mesure disposés dans ledit récipient (9), pour mesurer toute irrégularité de l'éclairement pendant l'opération d'exposition.

29. Appareil selon la revendication 7, dans lequel ledit récipient (9) comporte un élément utilisable en tant que référence en ce qui concerne le positionnement sur une autre partie desdits moyens de maintien (12).

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30. Appareil selon la revendication 1, comprenant en outre des moyens pour établir au moins une connexion électrique, une communication pneumatique et une communication de vide avec ledit récipient (9).

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31. Appareil selon la revendication 1, comprenant en outre des moyens pour mesurer l'indice de réfraction de la matière liquide dans ledit récipient (9).

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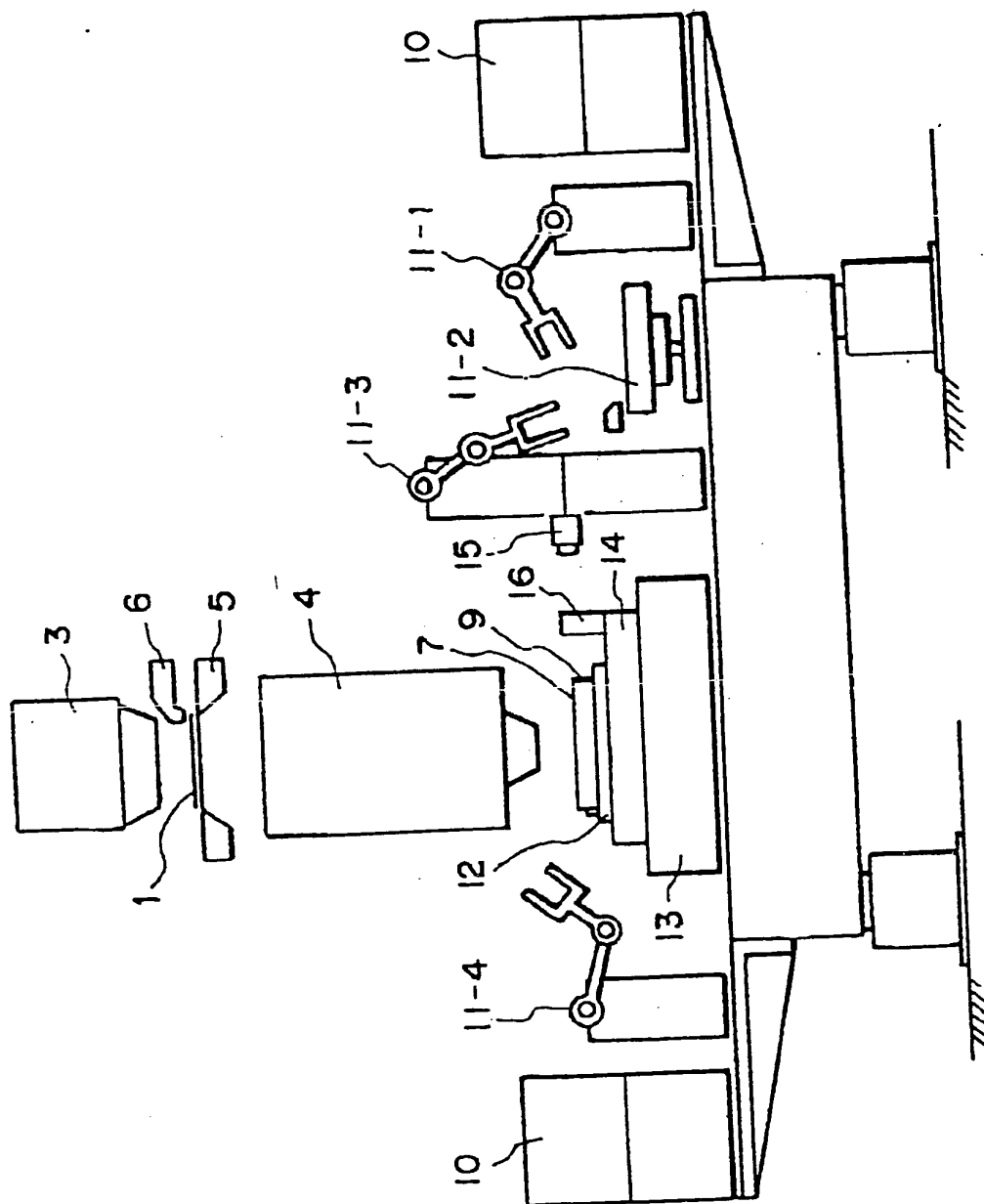
35

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1911

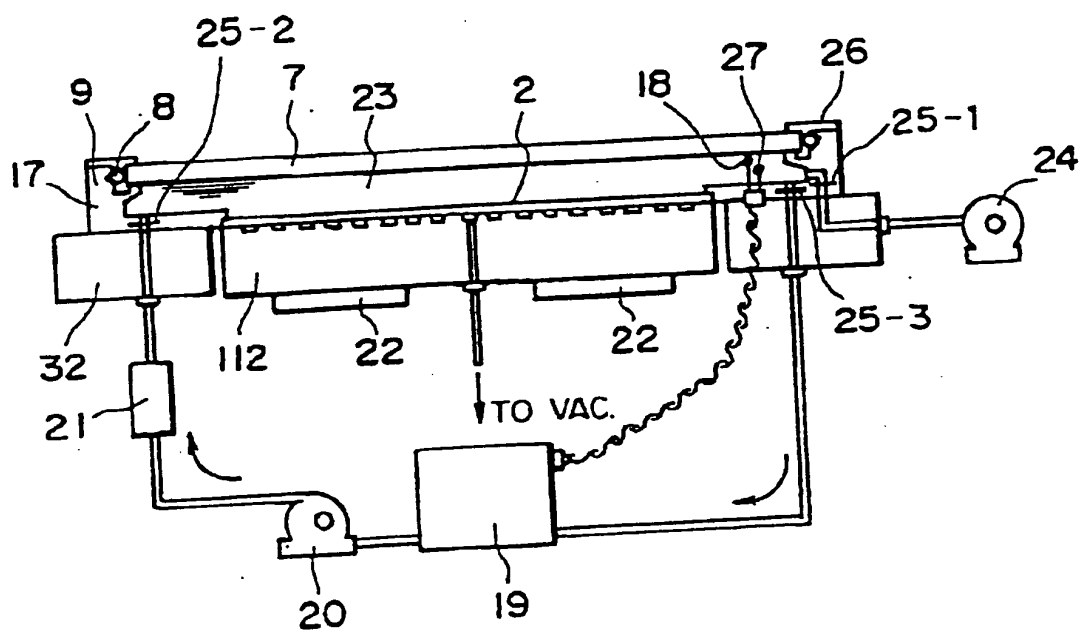


FIG. 2

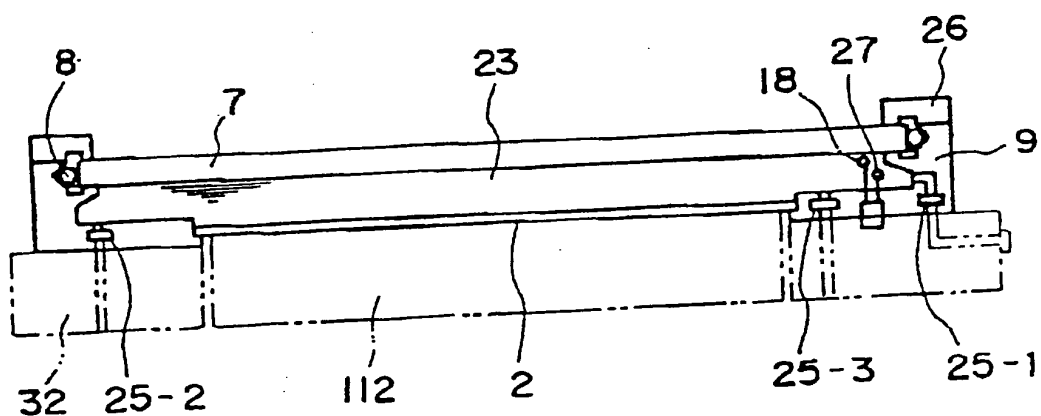


FIG. 3

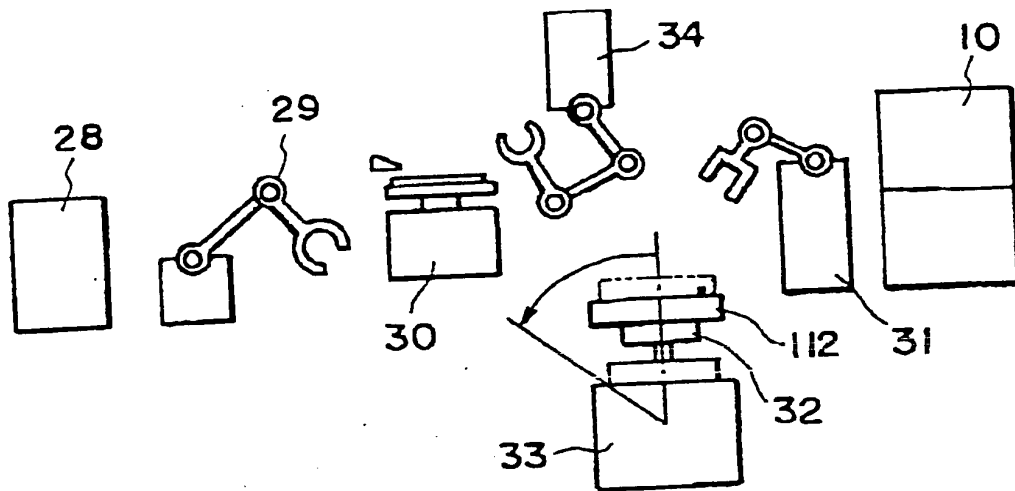


FIG. 4

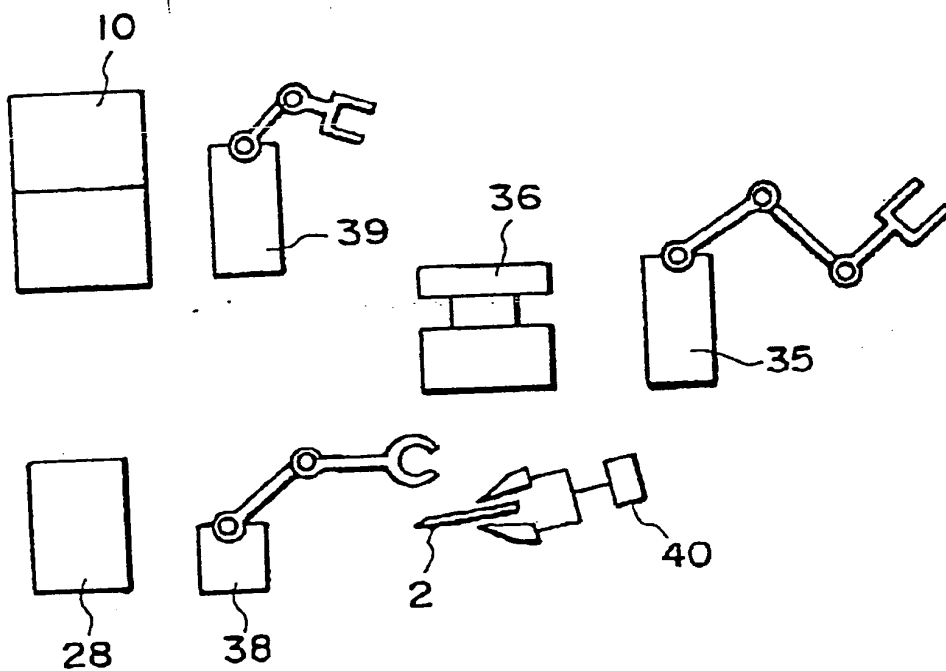


FIG. 5



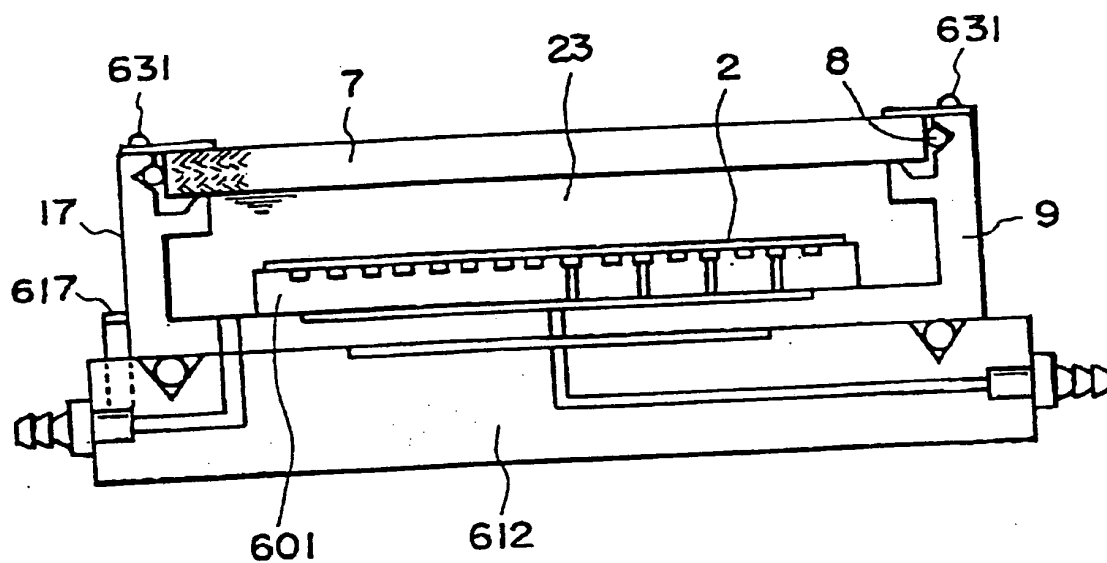


FIG. 6

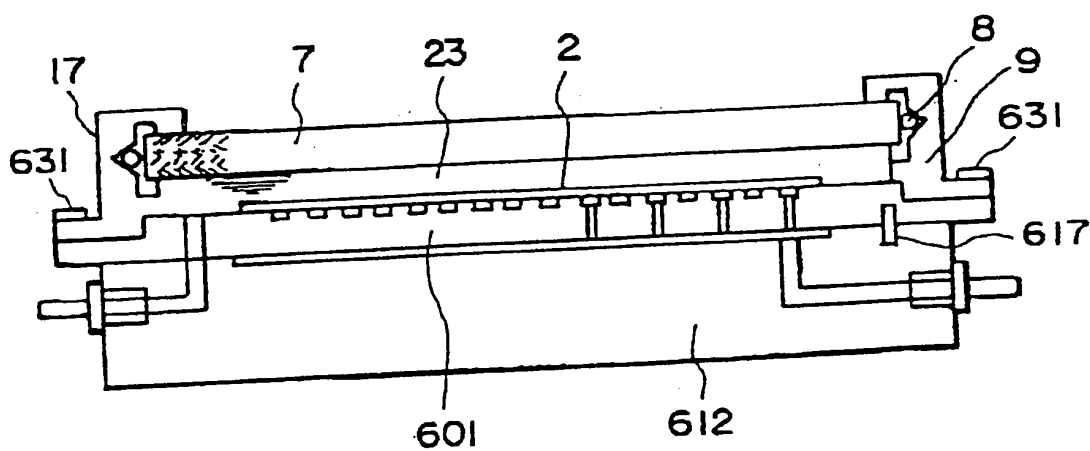


FIG. 7

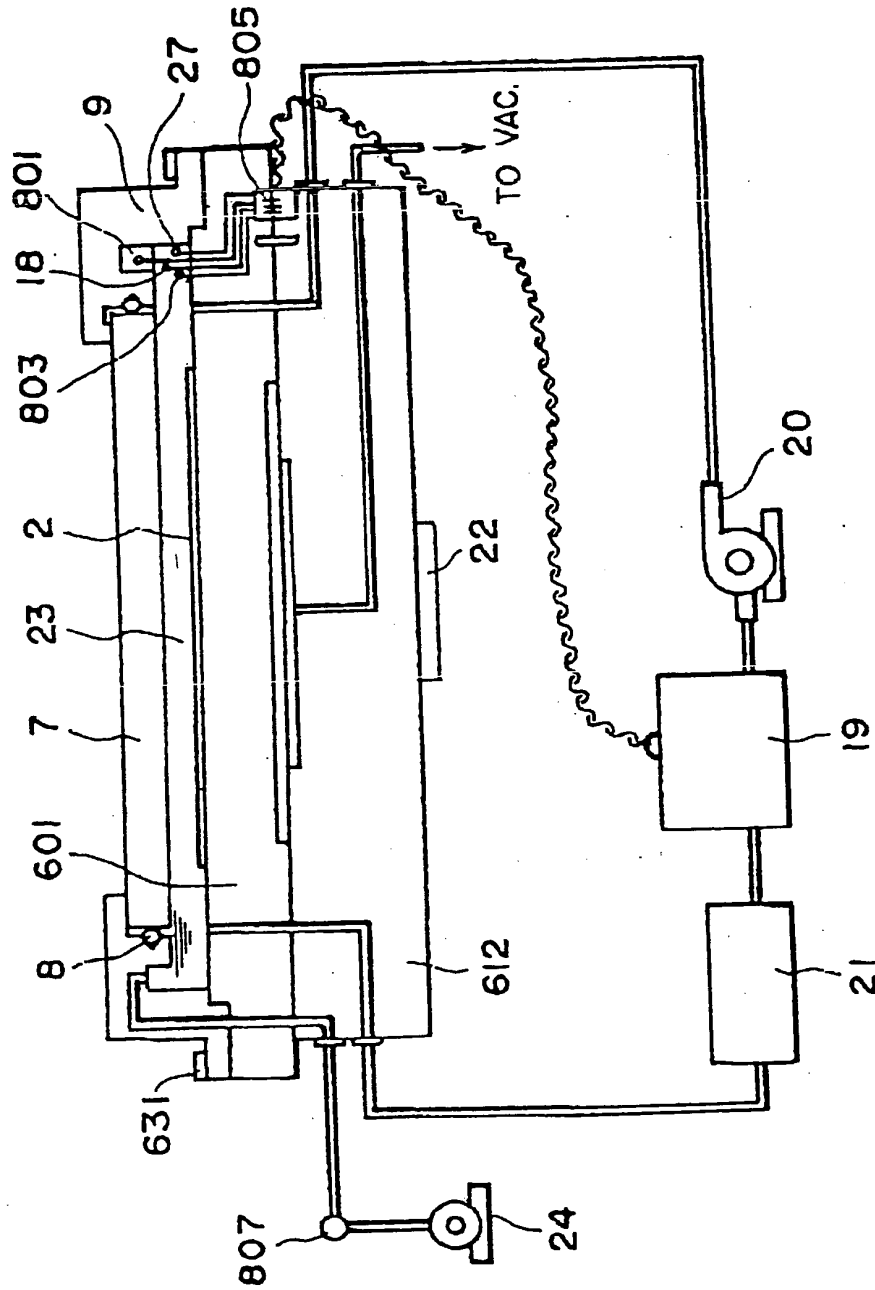


FIG. 8

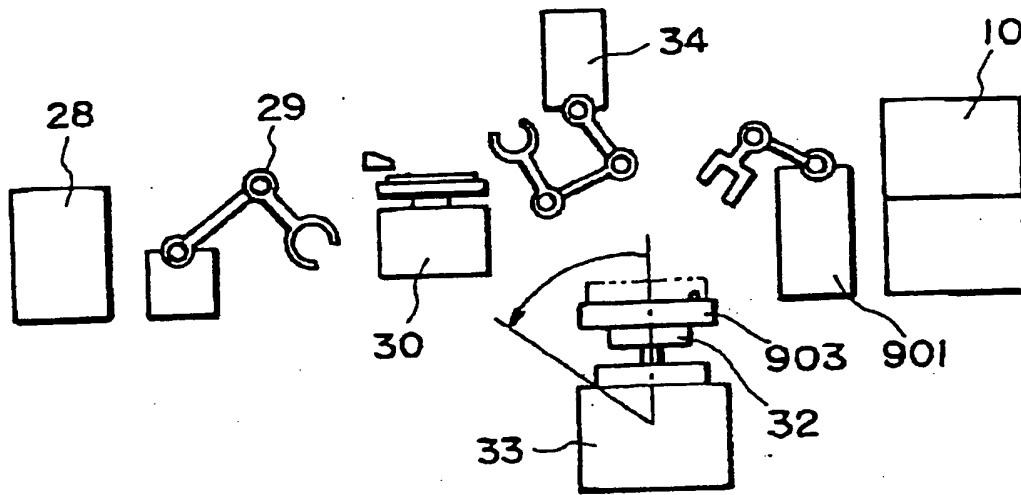


FIG. 9

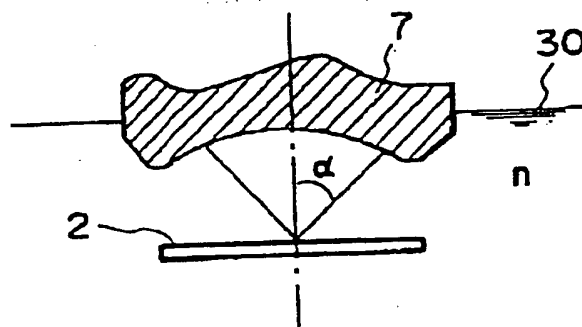


FIG. 10